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## MATERIALS RESEARCH LABORATORY

MELBOURNE, VICTORIA

TECHNICAL NOTE

MRL-TN-539



# MINEHUNTER INSHORE SHOCK TRIALS - PHASE 2: A LIMITED SHOCK TRIAL FOR DEVELOPING TRIAL METHODOLOGY AND LOGISTICS

D.J. Hatt, P.P. Elischer, G. Campanella
and M.G. Wolfson



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ABSTRACT

Phase 2 of the Australian inshore minehunter shock trials was conducted in the ocean off the coast from Townsville during September - October, 1986. The trial was the second in a three-phase programme which ended with the first-of-class shock testing of the Royal Australian Navy's prototype glass reinforced plastic (GRP) minehunter catamaran during November-December, 1987.

Described in the report are the operations undertaken during the trial by the Materials Research Laboratory, Defence Science and Technology Organisation, Melbourne. The operations were conducted onboard an aircraft water lighter which could only be subjected to low shock levels. The operations involved explosive charge firing, the collection of underwater explosion data, and the use of shock motion measuring instrumentation and high-speed cine cameras. Some examples of typical motion and pressure-time histories are given.

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CONTENTS

CONTENTS
(Contd)

# MINEHUNTER INSHORE SHOCK TRIALS - PHASE 2: A LIMITED SHOCK TRIAL FOR DEVELOPING TRIAL METHODOLOGY AND LOGISTICS

## 1. INTRODUCTION

As described in detail elsewhere [1], the Materials Research Laboratory (MRL), Defence Science and Technology Organisation (DSTO), Melbourne, in association with the Royal Australian Navy (RAN), was tasked to develop a capability for shock testing the RAN's new inshore minehunter (MHI). The MHI is an Australian designed and built vessel constructed from glass reinforced plastic (GRP)/foam sandwich material. Since ship shock tests are quite large and complex, and had not been conducted in Australia before, a three-phase programme was adopted to cope with this new requirement. The final phase culminated in the testing of HMAS SHOALWATER, one of two prototypes, during December 1987.

During the Phase 1 trial, a sample of the shock testing instrumentation and shock mounting techniques proposed for use on the Phase 3 trial were proven [1]. The materials and construction techniques for the prototypes were also re-evaluated. The Phase 2 trial was then conducted off the coast of Townsville, North Queensland, during September and October 1986. This trial was conducted in order to gain experience in conducting such trials at sea and also to gain data to prove the trials methodology. In addition, two trials of opportunity were conducted, one in support of an MRL task to study the effects of burial on the performance of sea mines and the other involving shock testing of a minesweeping magnet that has been developed by MRL DSTO (Sydney).

The "target" vessel for the trial was an Aircraft Water Lighter (AWL) which has a steel catamaran hull (Fig. 1). Since the AWL could only be subjected to shock levels much lower than those used for testing the prototype, it was not intended for use in the further evaluation of instrumentation and shock mounting techniques for their shock resistance. However, the catamaran hull form was needed for assessing the likely success of a particular Phase 3 photoinstrumentation requirement. The AWL was also an ideal test platform since it could accommodate a transportable instrumentation laboratory (modified ISO shipping container) and allowed a sufficiently complex trials arrangement to prove the methodology for the Phase 3 trial.

An important aspect of the Phase 2 trial was the collection of underwater explosion data which allowed various characteristics of the proposed charge geometries for the Phase 3 trial to be refined so that the MHI would be tested in accordance with NATO guidelines [2] as planned by the RAN Project Authority. Even with this data, there was still an element of uncertainty because of the effects of surface cut-off, seabed reflectivity, and precusor pressure pulses arising from ground shock. These are effects which arise because of the requirement for the testing to be conducted in shallow water with the charges placed on the seabed.

This report details the shock testing related operations undertaken by MRL during the trial and presents typical examples of the data obtained. Details of the mine burial and minesweeping magnet tests will be presented elsewhere. Underwater pressure-time histories, which form the bulk of the data, and environmental parameters are the subjects of separate reports [3, 4].

## 2. TRIAL SITE

Only two sites where large charges can be fired underwater were available on the eastern coast of Australia for this and the Phase 3 trial. During the early stages of planning, a site south of Rockhampton in Shoalwater Bay was considered but because of the operating difficulties posed for divers by strong tidal currents and poor visibility, the Royal Australian Air Force (RAAF) Bombing Range in Halifax Bay off the coast from Townsville was preferred.

The actual site was a few kilometres off Cordelia Rocks, approximately 30 km to the north of Townsville. The water depth was about 20 m, with a seabed of poorly sorted bimodal sediment consisting predominantly of fine sand with a significant clay fraction [4].

The preferred period for the Phase 2 and 3 trials was the April-August period when weather conditions for vessels and divers are best. In 1986, the earliest period that could be programmed was the September-October period. Fortunately, the weather conditions during the period were quite satisfactory.

Trials personnel travelled to and from the trial site daily on the RAAF search and rescue boat, WARANA. The typical embarking and disembarking times at Townsville were 7.00 am and 6.30 pm, respectively, with the travelling time being about 1 hour each way.

## 3. TRIAL SITE LAYOUT

As depicted schematically in Figure 2, the AWL was moored using concrete clumps arranged to give a 4-point mooring configuration. A pontoon was located about 500 m from the AWL and also moored using concrete clumps. A thick, buoyant polypropylene rope was deployed between the pontoon and the AWL to provide a means of attaching coaxial signal cables and deploying the underwater pressure gauges at fixed standoff distances from the explosive charges. Working from the AWL end, slack in the rope was taken up as much as possible in order to reduce the catenary formed by the tidal currents.

The explosive charges were laid on the seabed on either side of the rope as illustrated in Figure 3. This operation was performed by navy divers operating from the support ship, GPV BANKS.

## 4. CONDUCT OF TRIAL

The trial was conducted over a four week period as follows:

**Week 1.** This period was spent in Townsville setting up the shipping container on the AWL, installing instrumentation, sensors and power equipment, and preparing signal cables.

**Weeks 2 and 3.** This was the actual trial period held off Cordelia Rocks. At the start of the period, the buoyant rope and signal cables were deployed and underwater pressures gauges calibrated. This was followed by the firing of ten explosive charges. The firing schedule required one shot per day but on two days this was increased to two charges. After each shot, the underwater pressure records were examined to confirm their integrity. The underwater pressure gauges were relocated closer to the AWL after the first five shots to ensure that the remaining charges could be detonated at sites where the shock waves would not be distorted by craters from previous explosions. The final activity for this period was a recalibration of the underwater pressure gauges.

**Week 4.** The trial site was cleared and the AWL returned to Townsville where instrumentation was removed and packed for return to Melbourne.

## 5. INSTRUMENTATION

### 5.1 Objectives

During the trial, underwater pressure, acceleration, velocity and strain measuring instrumentation, together with high-speed cine cameras, were used. Apart from the underwater pressure measurements, the number of measurement channels was much less than that required during testing of the prototype. However, it was hoped that the number would be sufficient for estimating the time and effort required for setting up for the Phase 3 trial. Another objective was to use the instrumentation recording and control package, much of which had been developed at MRL, in an integrated form to ensure its viability for use in testing the prototype. Obtaining meaningful motion data (acceleration, etc) was not a specific requirement for the trial, principally because the AWL could be only exposed to low shock levels.

### 5.2 Underwater Pressure Measurements

Six underwater pressure gauges (PCB 138A Series) with peak dynamic pressure ranges between 35 MPa and 70 MPa were deployed (Fig. 4) for recording pressure-time histories and for determining shock arrival times. Four of the gauges were deployed at a depth of 2 m (which is approximately the MHI keel depth) while the other two were at 13 m. Two of the gauges at the 2 m depth were positioned within about 5 cm of each other. During deployment of the explosive charges their standoff distances were measured from a point on the polypropylene rope directly above these two central gauges. The other gauges at the 2 m and 13 m depths were deployed either side of these gauges, one set being at a distance of 10 m towards the pontoon while the other was 20 m towards the AWL.

As explained in the introduction, the purpose of the pressure measurements was to obtain underwater explosion data in order to refine the test conditions for the prototype. The configuration shown in Figure 4 was chosen so that the central gauges would experience about the same shock levels as those required for testing the prototype to its design level. The other gauges at the 2 m depth were then positioned so that one would experience shock levels greater than and the other less than the design level. From this data, Directorate of Naval Ship Design (DNSD) personnel were hoping to produce shock factor versus distance plots. The two gauges at 13 m were used for the mine burial experiment.

The pressure gauge measuring arrangement and calibration method are described in detail elsewhere [3]. Briefly, the pressure gauges were calibrated on site by subjecting them to a known pressure pulse generated by the detonation underwater of 500 g cast spherical pentolite charges which had been manufactured at MRL.

### 5.3 Shipboard Motion Measurements

An array of sensors comprising two accelerometers, a velocity gauge and two strain gauges were deployed in close proximity to each other on the hull in the starboard cargo hold (Fig. 1).

The accelerometers were ENDEVCO piezoresistive accelerometers (Model 2264A-5k-R) which were used with ENDEVCO PR signal conditioners (Model 4423).

The velocity gauge was of MRL manufacture (Fig. 5) and it was used with a DC differential amplifier as proposed for the Phase 3 trial. The amplifier would provide good common-mode rejection in the event that the electrical environment onboard the MHI was excessively noisy.

The strain gauges were SHINKOH gauges (SR-4, 30 mm) which were used with SHINKOH Strain Meters (Model DAS-407).

### 5.3.1 Gauge Mounting Procedures

Using the same method as that proposed for the Phase 3 trial, the accelerometers were fastened to 60 mm diameter aluminium discs which in turn were fastened to the hull with epoxy resin (Fig. 6). For improved adhesion the bottom of the discs had been sandblasted and vapour degreased using trichloroethylene. The hull surface was prepared by mechanical grinding using an angle grinder and belt sander, followed by manual working with abrasive paper and then cleaning with methyl ethyl ketone followed by freon.

The method of mounting the velocity gauge was again the same as that proposed for the Phase 3 trial. The gauge was fastened to a large aluminium disc by means of a threaded stud. The surfaces of both disc and hull were prepared in a similar fashion to that used for the accelerometers and then bonded together using epoxy resin.

Preparation of the surface before fastening the strain gauges was a very laborious process involving mechanical grinding and sanding followed by manual polishing with various grades of abrasive paper. The preparation and installation time for the two gauges amounted to about 1-1/2 days in total.

### 5.3.2 Gauge Calibration

The accelerometers were calibrated at MRL before and after the trial and also at Townsville just prior to the sea trial.

Calibration was performed up to + 500 *g* by dropping a standard accelerometer to which the test accelerometer was attached in piggy-back fashion. The standard accelerometer had been recently calibrated by a National Association of Testing Authorities (NATA) certified laboratory. The sensitivities obtained for the accelerometers were generally within a few percent of those given by the manufacturer. The calibration arrangement and an example of the output signals are shown in Figure 7.

A calibration apparatus (Fig. 8), specially developed for the Phase 3 trial, was used to determine the sensitivity of the velocity gauge. This entails dropping the gauge down a metal tube and measuring the time for it to fall through a known distance just before it impacts an anvil, thus enabling the impact velocity to be calculated. The time interval is measured using a simple optoelectronic technique. Confidence in this method was established by comparing results with those obtained using high-speed cinematography. Agreement within 5% was obtained for velocities up to 2.5 m/s.

Calibration of the strain measuring system was effected by using the strain meter's internal calibration circuit which in turn was initiated by a sequence timer via an appropriate interface circuit.

### 5.3.3 Photoinstrumentation

Two high-speed cine cameras (LOCAM High G) were used during the trial, both operating at 500 frames/s. One was shock mounted on the aft bulkhead in the starboard engine room of the AWL (Fig. 1) viewing an engine 3-4 m from the camera. The other was used, shoulder mounted, onboard the support ship which was stationed approximately 500 m from the AWL. The onboard camera used a specially developed shock mounting system utilizing "X-mounts" which was tested during the Phase 1 trial [5]. A photograph of the shock mounted camera, with flashbulb reflectors fitted, is shown in Figure 9. Black and white cine films were used exclusively for the camera onboard the AWL and colour for the other.

For the onboard camera, tungsten halogen lighting was used for the first shot but produced a film that was too underexposed. Flashbulb illumination was used for all subsequent shots and produced satisfactory results.

As an early warning to the camera operator onboard the support ship, an orange strobe light, located on a mast attached to the instrumentation laboratory, was started 5 s before detonation time-zero. In addition, a flashbulb, also attached to the mast and appearing in the camera field of view, was fired coincident with the electric detonator firing pulse. Simultaneously the event LED [5] in the AWL camera was pulsed, thus providing time correlation for both high-speed cameras with charge firing.

Still photography, although undertaken on an opportunity basis, provided coverage of most instrumentation aspects of the trial. Further coverage of parts of the trial was obtained by means of videography.

## 5.4 Instrumentation Laboratory

For housing the instrumentation onboard the AWL, an ISO shipping container was specially modified by MRL to function as a transportable, air conditioned laboratory comprising work benches, storage space for equipment and tools, power reticulation, and recording and control instrumentation installed in two shock-mounted aluminium racks (Fig. 10).

The container was mounted to the deck of the AWL by means of four brackets welded to the deck, the brackets having spigots that fitted into the lifting points of the container.

## 5.5 Power

Power for instrumentation and equipment was provided by a 15 kVA diesel generator. The generator was "grounded" to the AWL by means of a heavy copper braid fixed to a bracket welded to the deck. The switchboard in the instrumentation container was fitted with earth leakage detectors on all three phases. Instrumentation was operated from one phase, air conditioning from another and miscellaneous equipment from the third. High-speed cameras were battery operated.

The generator was originally required only to operate the instrumentation between shots. For a shot, the intention had been to shut down the generator and to switch over to operating from a 1 kVA inverter (INVERTECH Model No. INV-1K-FF) which has an operation time of about 45 minutes from freshly charged batteries (EXIDE Type 85). However, this procedure was abandoned when it was found that the inverter caused the sequence timer to malfunction.

## 5.6 Explosive Charge Firing

### 5.6.1 Calibration Charges

Firing of the explosive charges for calibration of the underwater pressure gauges was carried out by MRL personnel. With the help of Navy divers, the gauges and charges were suspended from a raft constructed from aluminium channel and expanded polystyrene blocks. The initiation of the spherical pentolite charges was by means of L2A1 electric detonators and small PETN boosters placed in cylindrical cavities in the charges. The detonator was held in place by modelling clay and the whole assembly was supported by a nylon stocking as shown in Figure 11. In order to ensure compatibility with the recording and control instrumentation, an MRL manufactured low voltage firing unit (LVFU) was used to initiate the detonator.

The pre-trial calibration site for the pressure gauges was about 300 m from the AWL. The firing cable ran along the polypropylene line to the pontoon and then back to the 300 m position. The post-trial calibration site was only 30 m from the AWL with the firing cable going directly from the AWL to the site.

### 5.6.2 Main Charges

The main charges were Mk 84 general purpose bombs and AS Mk 6 mortar bombs which were deployed and fired in a sequence chosen to avoid cratering of the seabed between charge sites and the pressure gauges. The deployment and arming of these charges were the responsibility of the navy divers. They used a plastic explosive charge mounted on the bomb case to initiate its high explosive filling. The plastic explosive was initiated using detonating cord (ICI Redcord) which in turn was initiated by an L2A1 electric detonator. The detonating cord ran from the bomb on the seabed to the surface where the cord, detonator and a fibre-optic time-zero cable were joined and attached to a float. Firing of the charges was carried out by MRL personnel using the LVFU.

The main charges were fired using the calibration (pre-trial) firing cable, sometimes with an extra length added. The resistance of this long firing cable (90 ohms typical) was large enough to cause the nominal 300 V firing pulse to be reduced to a marginal value at the detonator. This was thought to be the reason for a misfire that occurred on one occasion where an extra long firing cable was used, with a significant but unknown amount left coiled on its reel thereby increasing cable inductance as well as resistance.

### 5.6.3 Detonation Time-Zero Pulse

Each charge-to-pressure gauge standoff distance was calculated using the time for the shock wave to travel from charge to gauge and the known shock wave velocity. These times were determined using the pressure gauge and time mark signals recorded on the instrumentation magnetic tape recorder.

To generate a time mark coincident with detonation of the charge, a fibre-optic method was used which involved joining one end of a fibre-optic cable to the detonating cord near the detonator and connecting the other end to an optoelectronic detector and amplifier circuit. This circuit was located on the pontoon with the output cable running along the polypropylene line to the AWL. The system was satisfactorily tested at MRL prior to the trial with a 70 m length of fibre-optic cable. However, during the trial at least twice that length of fibre-optic cable sometimes had to be used because of deployment difficulties. This would result in increased attenuation of light transmitted along the cable.

As a backup to the fibre-optic system, it was decided at the trial site to record a time mark derived from the firing pulse. Time-zero could then be derived from this mark provided the length of the detonating cord and the functioning time of the electric detonator were accurately known. The length of detonating cord was measured by the navy divers, so that from its well known velocity of detonation, the transit time for the cord could be calculated. However, the functioning times of the electric detonators were not known and thus post-trial tests were conducted at MRL using the same LVFU as used on the trial to determine the relationship between firing circuit resistance and detonator functioning time [6]. At the time of conducting the tests, a supply of L2A1 detonators was not available so detonators similar to the L2A1 had to be used. These preliminary tests have shown that when the cable resistance approaches 100 ohms, a marginal situation arises where the detonator may fail to function and functioning times are not very reproducible. Despite this lack of reproducibility, for those events where the fibre-optic system failed, the backup system proved to be useful because it was found that a small perturbation observed on the firing pulse (a capacitor discharge pulse) corresponded to the fusing of the bridgewire in the detonator.

## 5.7 Instrumentation Package

A schematic diagram of the instrumentation package is shown in Figure 12. With minor modifications and more transducer stations, it is essentially the package proposed for use during testing of the prototype.

At the heart of the package is a single 14-channel instrumentation magnetic tape recorder (AMPEX PR2230) which was the only recorder available for use during the Phase 3 trial. To enable the acquisition of an estimated 40 channels of motion data it was necessary to use a multiplexer in conjunction with the recorder. A multiplexing unit that allows eight narrow band signals (bandwidth of 2 kHz) to be recorded on one, wideband direct record channel (2 MHz, 305 cm/s tape speed) of the tape recorder was purpose designed and constructed at MRL. A time division technique is used in the unit [7]. Using five of these units, the 40 channels of data would thus only require the use of five tape recorder channels.

The underwater pressure measurement system required a bandwidth much greater than 2 kHz and hence these signals were recorded directly onto the recorder using FM record/replay modules.

For the automatic control of instrument functions (switch on/off and calibration) a microprocessor-based programmable sequence timer was also purpose designed and constructed at MRL [8]. A typical sequence that was used during the trial is illustrated in Figure 13. As shown, the sequence timer controls the tape recorder, the application of calibration signals to the multiplexer and strain units, lights and high-speed cine cameras, and explosive charge firing. Important operational features of the timer are the ability to manually abort the charge firing and the automatic abort provided in the event that the tape recorder fails to reach its operating speed.

## 6. RESULTS

### 6.1 Underwater Pressure Data

Just over 80% of the required pressure records were obtained, with records being lost due to sea water seeping through BNC to sub-miniature (SM) adaptors joining the main signal cables (coaxial, type UR 70) to the pressure gauge cables (coaxial, miniature low noise type). Of these records, only about 60% were useful for determining shock factor because some of the gauges exhibited a poor low frequency response [3].

Examples of satisfactory pressure-time records for the Mk 84 and AS Mk 6 bombs are shown in Figs 14 and 15, respectively. An example of a record obtained from a gauge with poor low frequency response is shown in Fig. 16 and an example of a calibration record is shown in Fig. 17. The average sensitivities obtained for the pressure gauges agreed fairly well with the manufacturer's values and the values obtained before and after the trial agreed with each other to within 5%.

By using the calculated sound speed for the sea water at the trial site and the measured arrival times standoff distances from the charges to the pressure gauges were determined to within ± 1 m.

### 6.2 Motion-Time Data

Examples of acceleration, velocity, and strain records are shown in Figs 18, 19 and 20, respectively. Peak velocities from uncorrected records were in the range 0.1

to 0.2 m/s while peak strains were in the range 100 to 200 $\mu\epsilon$. After low-pass filtering ($f_{-3dB}$ = 2 kHz), peak accelerations were in the range 15 to 50 *g*.

### 6.3 Photoinstrumentation

The exposure of the cine films from onboard the AWL was satisfactory when using the flashbulbs but underexposed when using the tungsten halogen lamps because of the large camera-to-subject distance involved. This was not expected to be the case for the tungsten halogen lamps at the Phase 3 trial as camera-to-subject distances would generally be less than 3 m.

Some of the black and white cine films were processed at the RAAF Base, Townsville, using a basic film processor belonging to MRL. This processor is very slow, taking some 2 hours per film, and has no facilities for varying processing conditions. Colour films were processed commercially on return to Melbourne.

One of the reasons for deploying a high-speed camera onboard the support ship was to see if flexing of a catamaran structure could be observed. This was of interest because it was a technique being considered for use during the Phase 3 trial. However, with the distance and wide field of view involved, the film results showed this would not be successful. Viewing of the cine films from the AWL camera showed that there was no observable motion arising from the underwater shock anywhere within the field of view.

The orange strobe light located on top of the instrumentation laboratory proved unreliable as an early warning signal, as it was not always visible from the support ship, particularly in bright sunlight. Consequently it was decided to also use TALKMAN C900, 40 mW, voice activated FM transceivers for relaying the countdown from the AWL to the support ship.

### 6.4 Firing Instrumentation

The firing system proved to be satisfactory. Some success was achieved also with the fibre-optic method for obtaining a time-zero fiducial mark, with failures of the system probably arising either from deployment difficulties by the divers or lack of adequate water-proofing of a signal cable joiner located between the pontoon and AWL. The deployment method that evolved on site precluded the testing of the actual fibre-optic cable used for a shot.

### 6.5 Instrumentation Laboratory

The modified ISO shipping container met the requirement for an instrumentation laboratory very well.

### 6.6 Summary of Instrumentation and Equipment Performance

A summary of the performance of the principal instrumentation and equipment used during the trial is given in Table 1.

## 7. DISCUSSION AND RECOMMENDATIONS

Calibration and deployment of the pressure gauges while working from a rubber dinghy proved to be quite difficult and time consuming. This was compounded by the unexpected problems encountered with water-proofing the BNC to SM adaptors. Many adaptors and cable end connectors needed to be replaced during the trial. Though it is believed a suitable technique for water-proofing these connections evolved during the trial, problems still occurred, probably because sea water had already migrated along the cable between sheath and braid. As the central conductor of the cables was at a potential of + 11 volts during operation, electrolysis quickly corroded the metal components of the connectors. This problem did not arise during Phase 3 as the pressure gauges were deployed within a few metres of the side of the MHI and hence the entire cable run was a continuous length of miniature low noise coaxial cable.

Several gauges were found to have poor time constant characteristics which were not revealed during calibration. In fact, these were not apparent until after close examination of the trial records that exhibited surface cut-off effects. The calibration method thus needed to be revised.

Sufficient shock factor versus distance data were generated to meet DNSD's requirements.

The method for deploying the pressure gauges and explosive charges during calibration needed revising as the raft was found to be unsatisfactory due to its lack of robustness in waves, the difficulty with deploying it into the sea from aboard the AWL (which was expected to be even more difficult from the MHI), and with mooring it at the required location.

The trial specification required that the explosive charges were to be positioned to an accuracy of ± 3 m. However, the distances calculated using the measured shock arrival times have shown that some charge positions were in error by as much as 9 m. Errors of this magnitude may have arisen because of incorrect positioning of the charges, movement of the buoyant rope after charge deployment, or a combination of both of these. It was therefore recommended that the arrival time method should again be used during the Phase 3 trial for ascertaining the actual standoff distance at the moment of detonation.

For the Phase 3 trial, it was proposed that the primary system for determining time-zero should be the fibre-optic system but with a maximum cable length of 70 m. The backup system was again to be used and as the firing cable would be much shorter than that used during the Phase 2 trial, the problem of unreproducibility of the detonator functioning time would be obviated.

During calibration of the accelerometers and velocity gauges they are allowed to free fall a short distance in plastic and metal tubes respectively. These tubes should be essentially vertical. Hence, some difficulties were encountered when trying to calibrate onboard due to the rocking motion of the AWL. Therefore, for the Phase 3 trial, it was decided that the calibrations should be performed onshore.

The post-trial calibration of the accelerometers at MRL revealed that one of them had sustained a 50% change in sensitivity at some stage following its calibration at Townsville. To obviate this problem during the Phase 3 trial, it was recommended that a portable battery-operated calibration exciter be used for checking the accelerometers following each shot.

It is believed that the high-frequency oscillations (approx. 30 kHz) seen in the acceleration records (Fig. 18) indicate that the resonant frequency of the accelerometer/mount system was excited by the shock pulse. The useful frequency response range of the accelerometer is only about 8 kHz. The accelerometers should have been mounted on mechanical filters (e.g. BRUEL & KJAER UA 0559) to prevent these excitations. Particular attention was given to this matter during the Phase 3 trial whenever accelerometers were mounted on metal surfaces.

The time and resources required for installation of strain gauges was much more than expected. As more than 30 gauges were to be installed for the Phase 3 trial an attempt needed to be made to reduce this installation effort. In the event, the contingency plan of extending the pre-trial period allocated for installation of instrumentation by one week was implemented.

No significant problems were encountered with the operation of the photoinstrumentation. It was recommended that a more suitable processing machine would be required for on-site processing of black and white cine films during the Phase 3 trial. Also, the use of TALKMAN, C900, 40 mW FM transceivers was recommended for relaying the countdown from the MHI to the camera operator on the support ship. As previously recommended [5] both lighting options - flashbulbs and tungsten halogen lamps - were to be retained for the Phase 3 trial. The use of a high-speed camera located on the support ship to observe flexing of the MHI catamaran structure would not be successful and therefore was not recommended.

Switching from generator to inverter was the procedure that had been proposed for the Phase 3 trial. (The use of an inverter was chosen originally because it was considered that it would be less susceptible to shock damage than an AC generator.) Unfortunately, operation of instrumentation during the Phase 2 trial using the inverter was not tested as planned. This testing was required in order to confirm that the lead-acid batteries could sustain daily deep cycling for a period of 2 weeks. However, as the inverter, supported by X-mounts, was tested during the Phase 1 trial and found to function correctly in the onboard shock environment, and as limited laboratory tests conducted before the Phase 2 trial indicated daily deep cycling of the batteries during the Phase 3 trial would be feasible, it was recommended that the inverter be used for the Phase 3 trial. In making this recommendation, it was assumed that the compatibility problems with the sequence timer would be resolved.

The daily working hours during the trial were generally some 11 hours and though the instrumentation team coped well enough, it was recommended that the hours for the Phase 3 trial should be no more because the level of instrumentation was expected to be both more intensive and extensive and hence more demanding. It is believed that the Phase 2 trial clearly demonstrated that no more than 1 shot per day would be feasible for the Phase 3 trial.

## 8. CONCLUDING REMARKS

The principal reasons the RAN and DSTO had for conducting the Phase 2 MHI shock trial were to gain the experience and data needed for confirming the suitability of the methodology and logistics proposed for the Phase 3 MHI shock trial. The operations undertaken by MRL in supporting the trial have been presented herein. With minor exceptions only, these operations, involving mainly the instrumentation, explosive charge firing, and underwater explosion phenomena aspects of shock testing, had a successful outcome.

As a consequence of the preliminary trials, viz. Phases 1 and 2, it was considered that Australian shock testing knowledge and skills had attained the necessary level of sophistication needed for testing the MHI prototype.

## 9. ACKNOWLEDGEMENTS

It is a pleasure to acknowledge the considerable assistance of the other members of the MRL trials team, Lt Cmdr Noel Stewart and the Navy diving team (CDT 4), RAAF Base, Townsville for making available a darkroom and workshops and the crew of WARANA.

## 10. REFERENCES


1. Elischer, P.P. and Campanella, G. "Minehunter Inshore Shock Trials - Phase 1". MRL report in course of preparation.

2. "Standard Underwater Explosion Test for Operational Surface Ships and Craft". North Atlantic Treaty Organization (NATO), Standardization Agreement No. 4137. RESTRICTED.

3. Opalko, J.A. (June 1988). "Minehunter Inshore Shock Trials - Phase 2: Underwater Pressure Measurements (U)". MRL-TN-535, Materials Research Laboratory, Melbourne, Victoria. CONFIDENTIAL.

4. Bishop, J.H., Lewis, J.A. and Learmonth, L.A. "Environmental Parameters at the MHI Phase 2 Shock Trial Site". MRL report in course of preparation.

5. Wolfson, M.G., Lee, K.J. and Kinsey, T.J. (May 1988). "Minehunter Inshore Shock Trials - Phase 1: Photoinstrumentation Development". MRL-R-1120, Materials Research Laboratory, Melbourne, Victoria.

6. Wolfson, M.G. and Lee, K.J. "Variation of Functioning Time with Firing Circuit Resistance for Electrical Detonators". MRL report in course of preparation.

7. Campanella, G. and Box, P. "Data Multiplexing System for Use on Ship Shock Trials". MRL report in course of preparation.

8. Lee, K.J., Wolfson, M.G. and Lambrellis, M. "A Microprocessor Based Sequence Timer". MRL report in course of preparation.

## TABLE 1

Instrumentation and Equipment Performance

| Instrument/Equipment | Performance | Repairs Required | Modifications Required |
|---|---|---|---|
| Multiplexer/Demultiplexer | Satisfactory | No | No |
| Ampex PR2230 Tape Recorder | Satisfactory except one data channel lost through malfunction. | Yes - minor | No |
| Time Mark Generator | Satisfactory | No | No |
| Transient Waveform Recorders | " | " | " |
| AC Voltage Standard | " | " | " |
| Sequence Timer | Satisfactory except not compatible with inverter and tape recorder. | " | Yes |
| Flash Bulb Firing Unit | Satisfactory | No | No |
| Time-Zero Indicator | Less than satisfactory for fibre-optic cable lengths used. In addition, deployment method used did not allow final system check. | No | Yes |
| X-Y Plotter | Satisfactory | No | No |
| Y-t Plotter | " | " | " |
| 1.0 kVA Inverter | Not used because of compatibility problems with sequence timer. | " | " |
| Strain Gauge Meters | Satisfactory except for noise problems with one unit. | Yes - minor | " |

**TABLE 1**
(continued)

| Instrument/Equipment | Performance | Repairs Required | Modifications Required |
|---|---|---|---|
| Line Power Units | Satisfactory | No | No |
| Distribution Boards | " | " | " |
| Cathode Ray Oscilloscope | " | " | " |
| Sweep Generator | " | " | " |
| Low Voltage Firing Unit | " | " | " |
| Sequence Timer VDU | " | " | " |
| Battery Charger | Satisfactory until it sustained water damage | Yes - extensive | " |
| 16 mm B&W Film Processor | Not satisfactory - processing speed fixed and too slow. No facility for forced processing. | No | " |
| Locam HS Cameras | Satisfactory except for temporary malfunction with speed control circuit of one of them. | Yes - minor | " |
| 35 mm Cameras | Satisfactory except for minor problem with one of them. | Yes - routine cleaning | " |

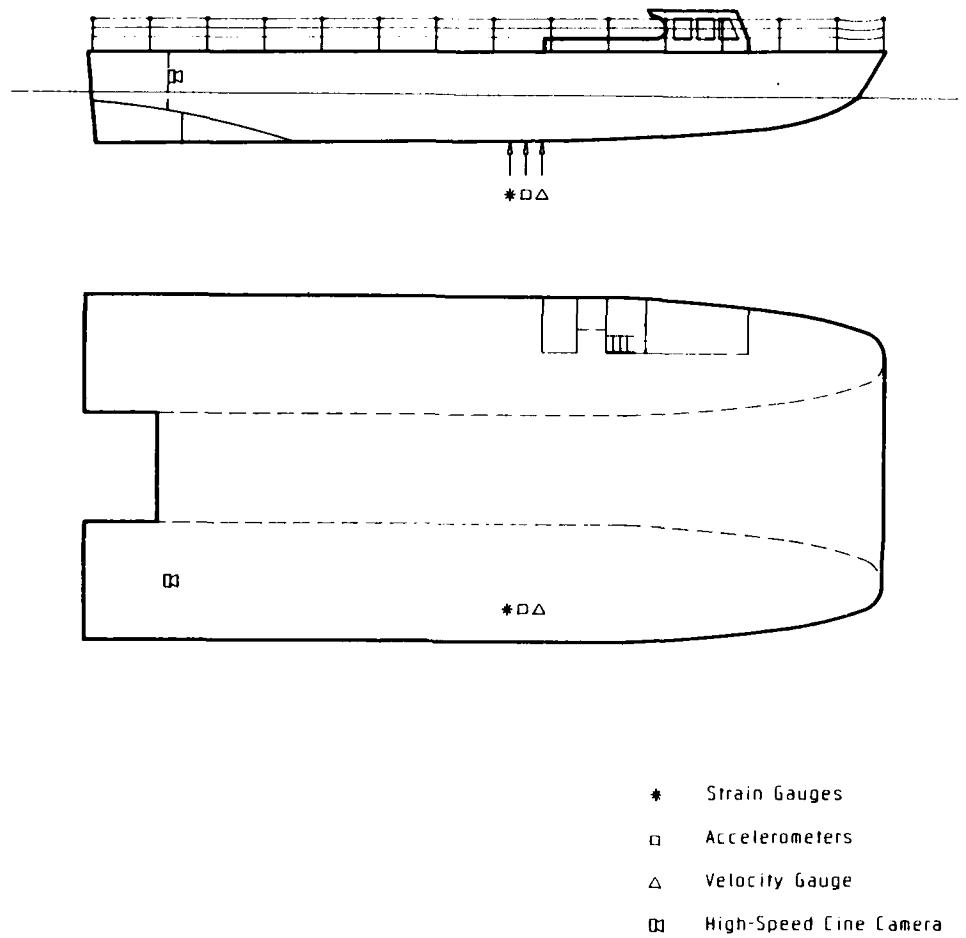



**FIGURE 1 Sensor and high-speed cine camera locations onboard the Aircraft Water Lighter (AWL).**

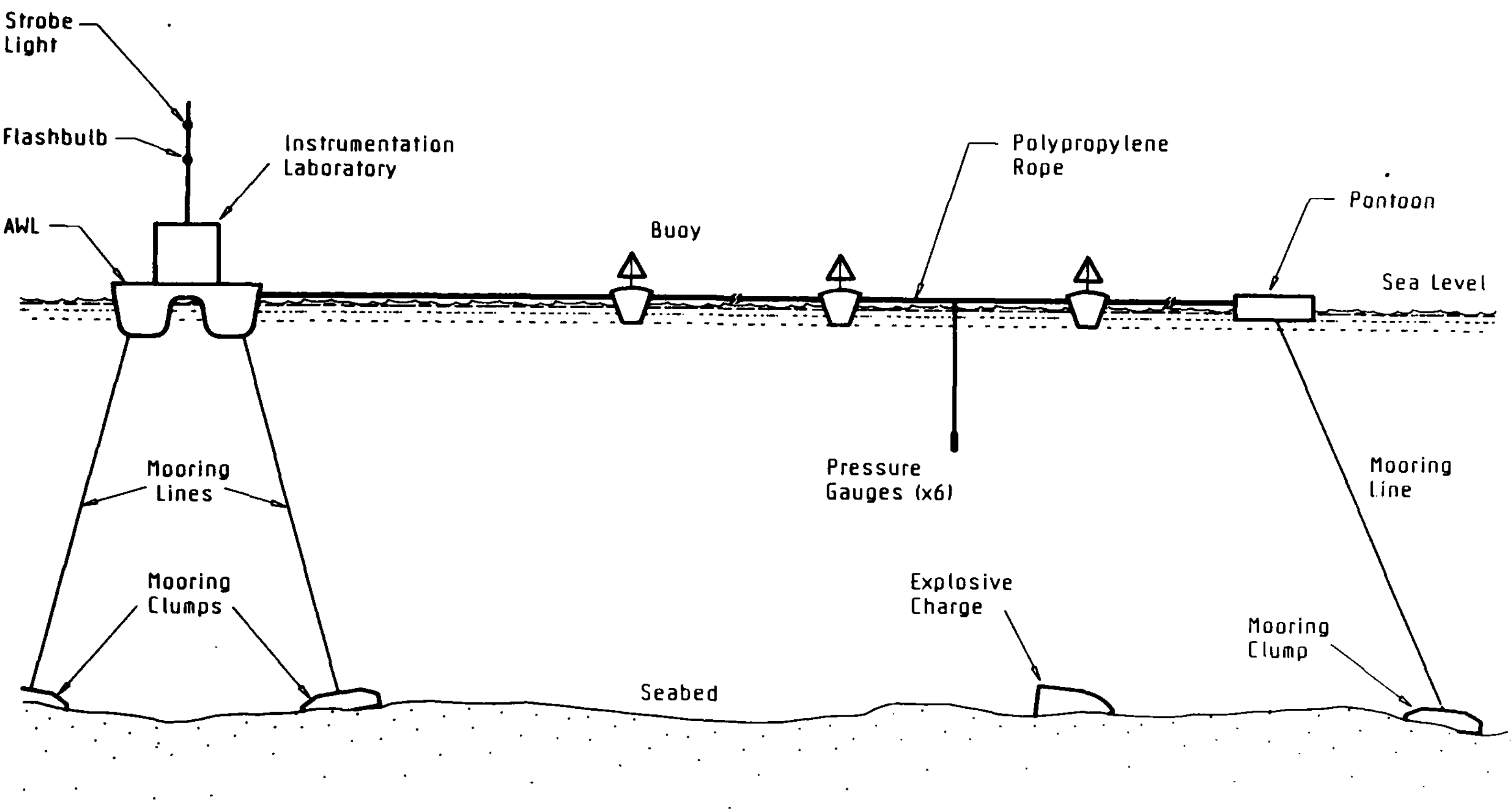



**FIGURE 2** Schematic diagram of trial site layout.

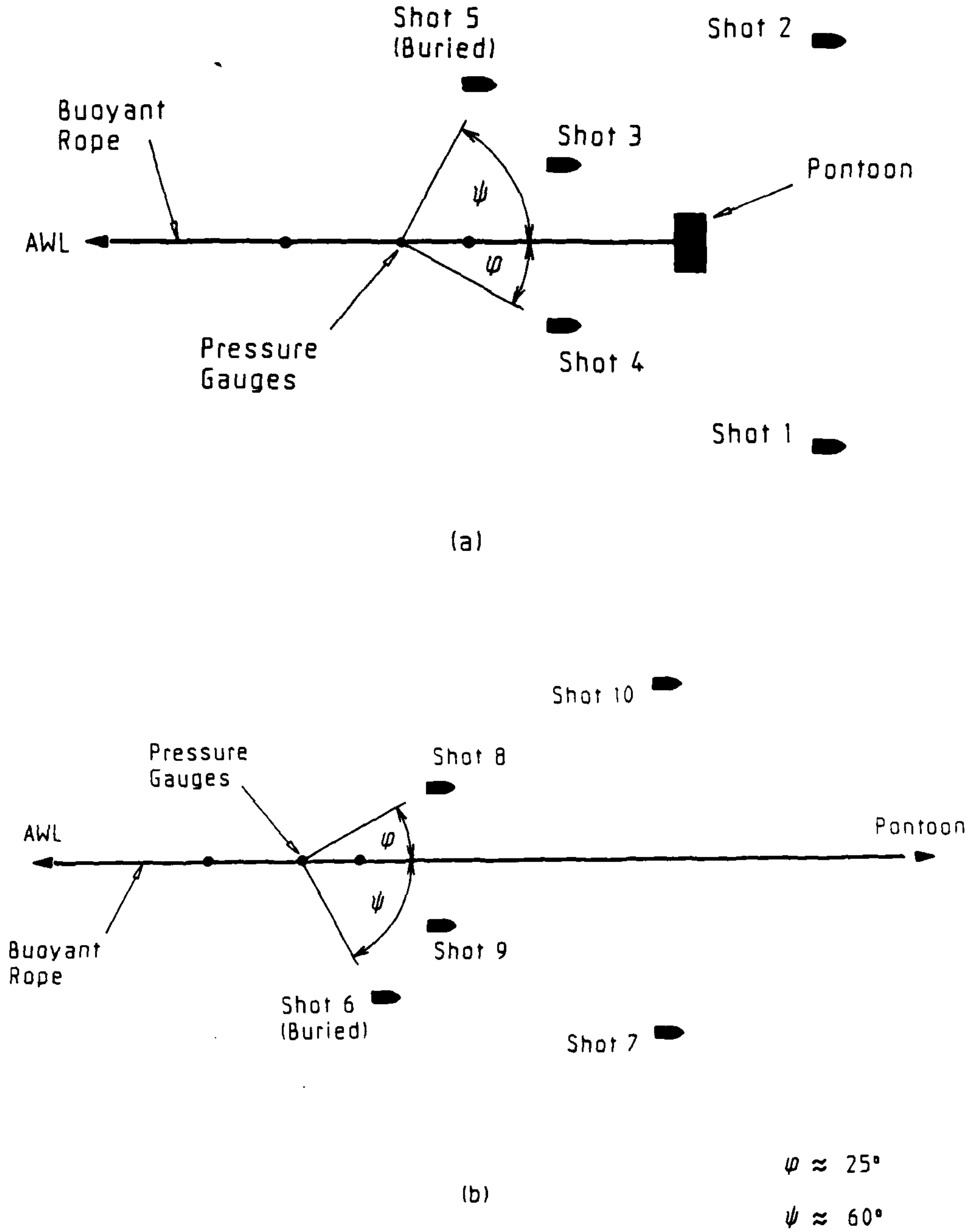



**FIGURE 3** **Schematic diagrams showing general arrangement for explosive charge sites. Diagram (a) is the arrangement used for the first series of explosions and (b) is for the second.**

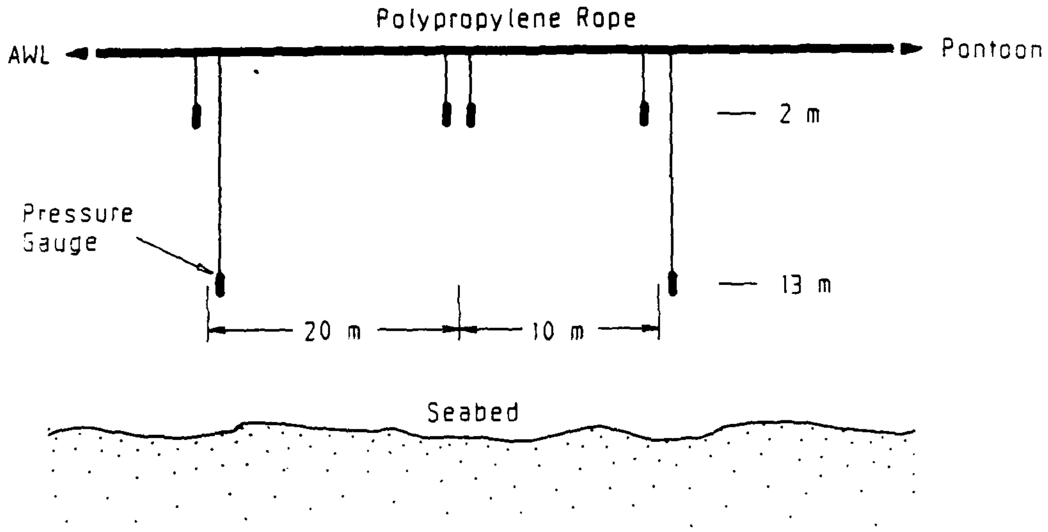



**FIGURE 4** Underwater pressure gauge layout.

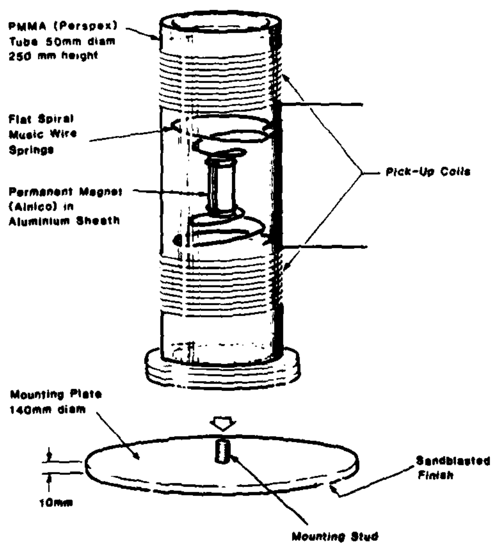



**FIGURE 5** Schematic diagram of a velocity gauge.

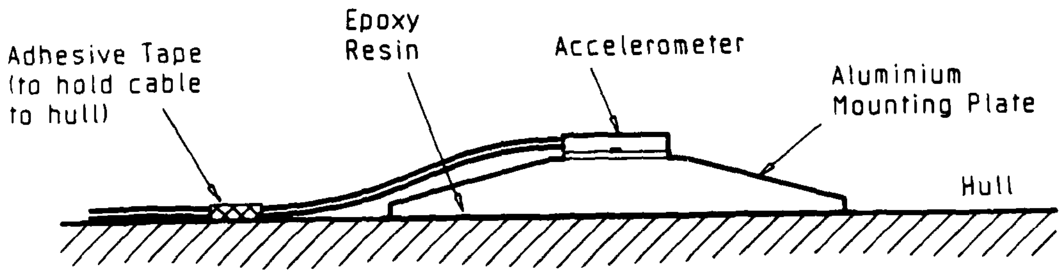
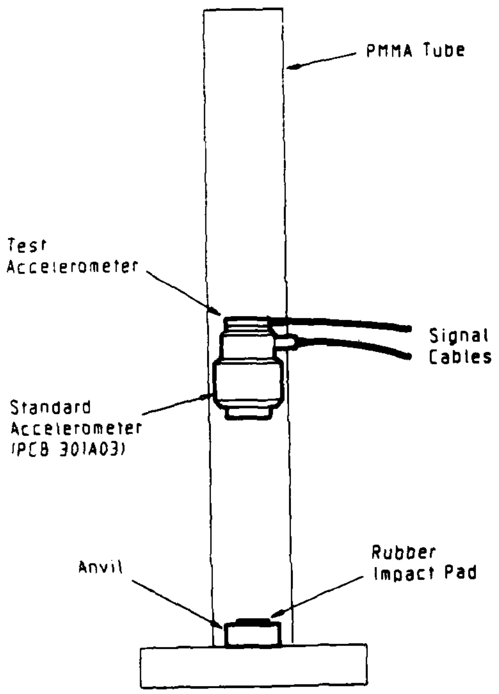



**FIGURE 6** **Schematic diagram showing method of mounting accelerometer.**



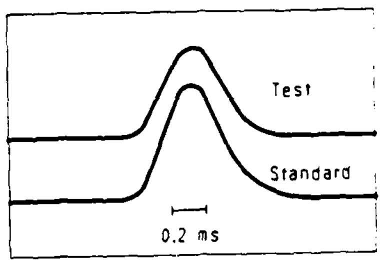




**FIGURE 7** **Arrangement used for calibrating the accelerometers. The accelerometers are raised and released in the tube by hand. Drop height of 100 mm corresponds to about 500 *g*. Also shown is an example of the output signals.**

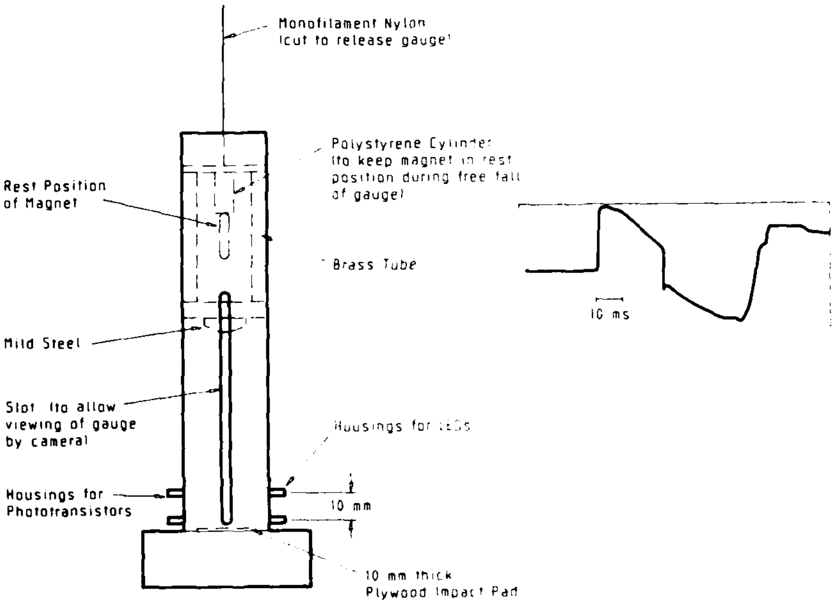



**FIGURE 8** Arrangement used for calibration of the velocity gauge. Drop height of 300 mm corresponds to about 2-1/2 m/s. Also shown is an example of a calibration record.

**FIGURE 9** Shock mounted LOCAM camera with flashbulb reflectors fitted.

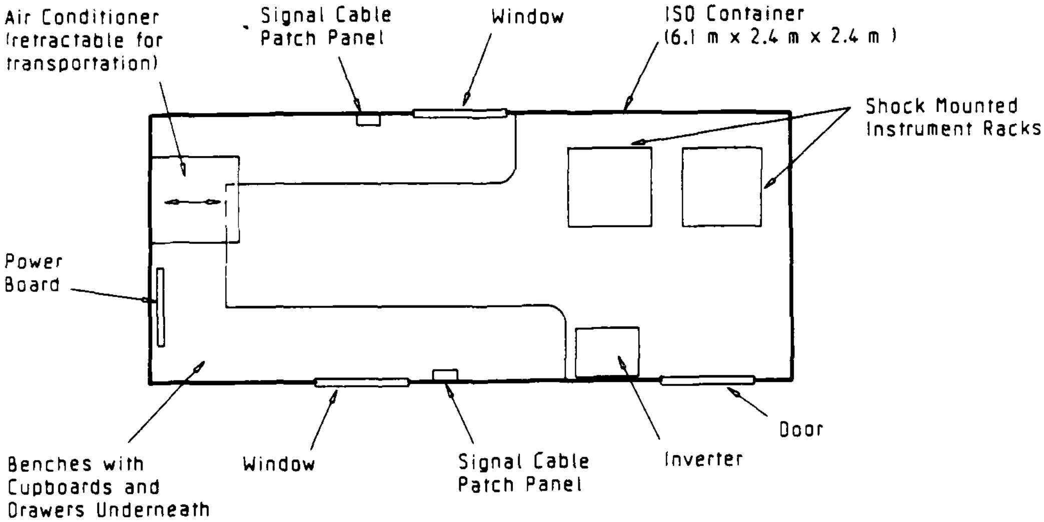



**FIGURE 10** Plan view of the Instrumentation Laboratory.

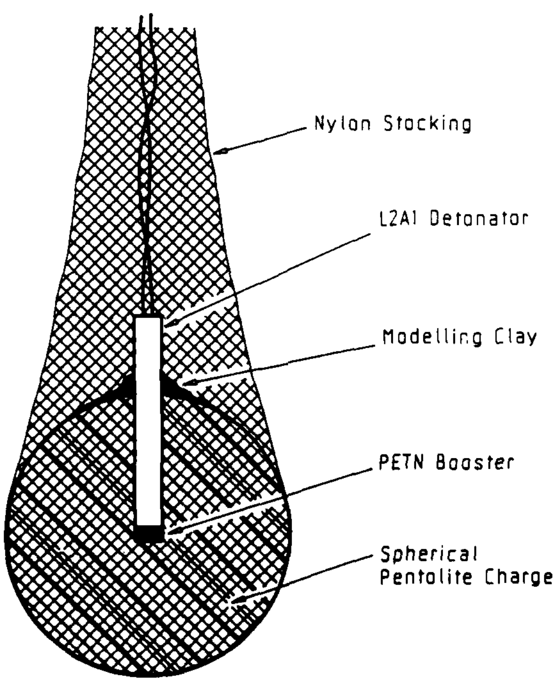



**FIGURE 11** Arrangement for deployment of explosive calibration charge.

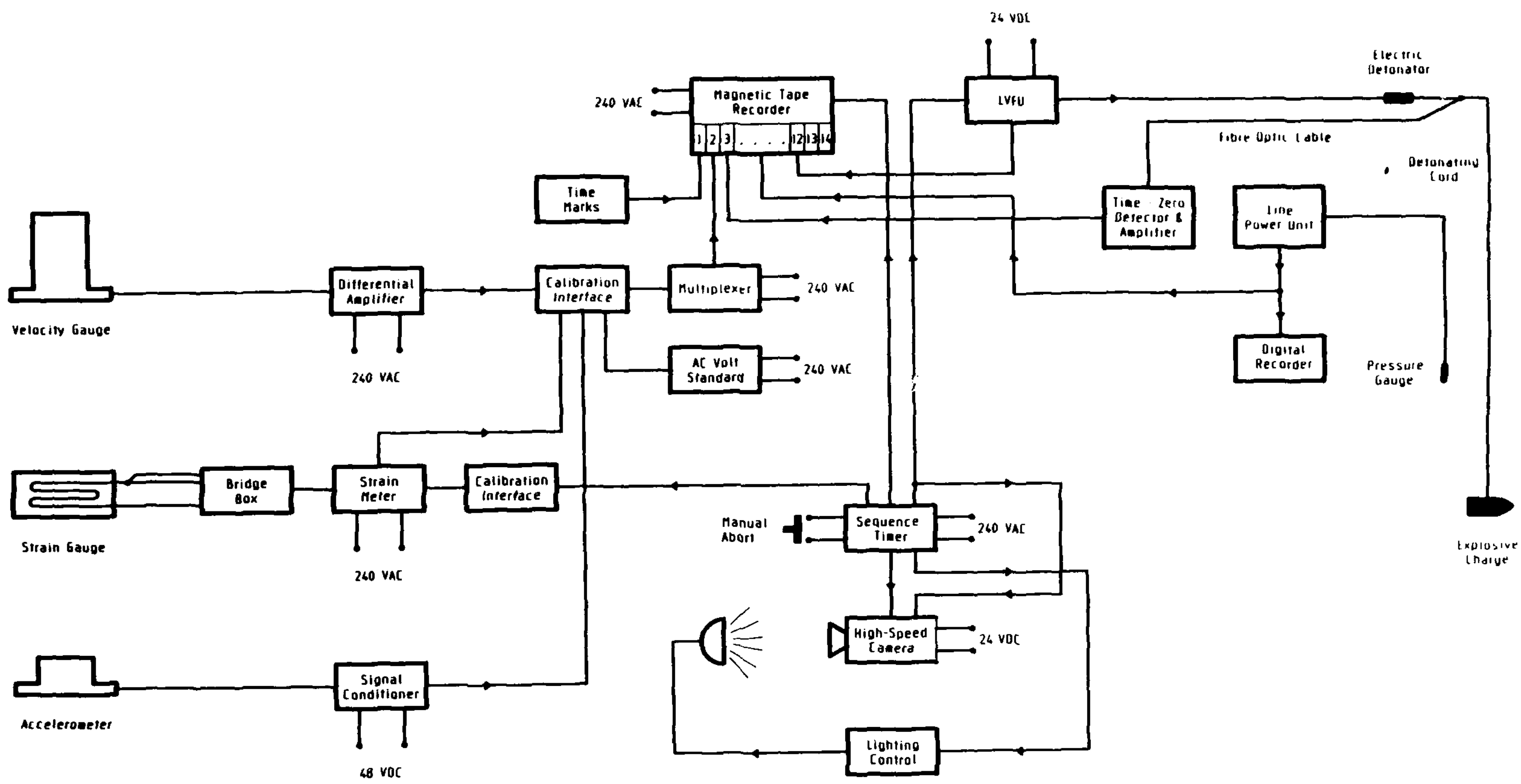



FIGURE 12 Instrumentation Schematic.

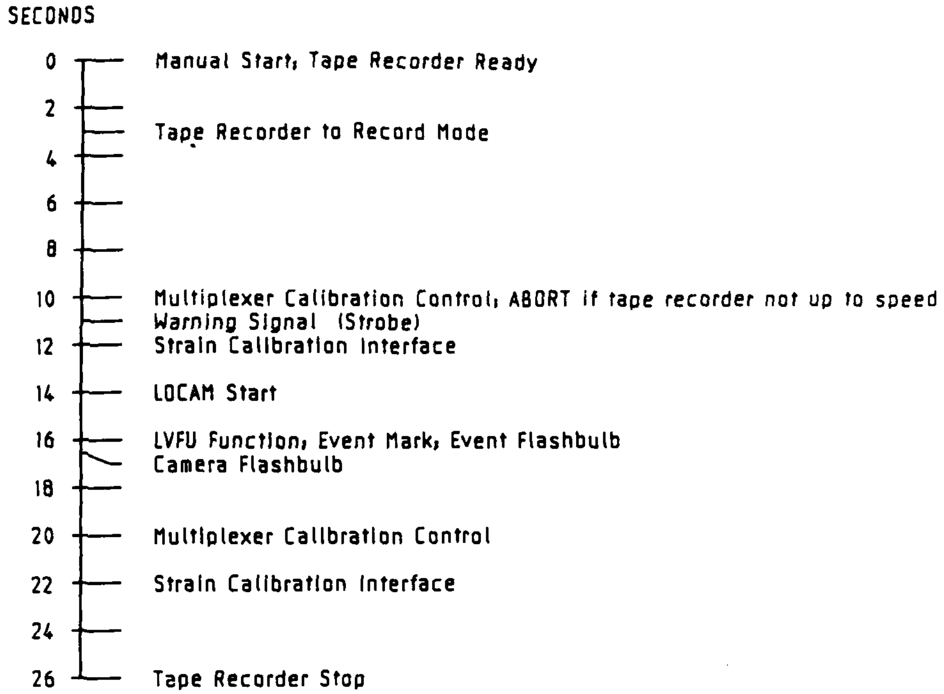



FIGURE 13 Typical sequence of events controlled by the Sequence Timer.

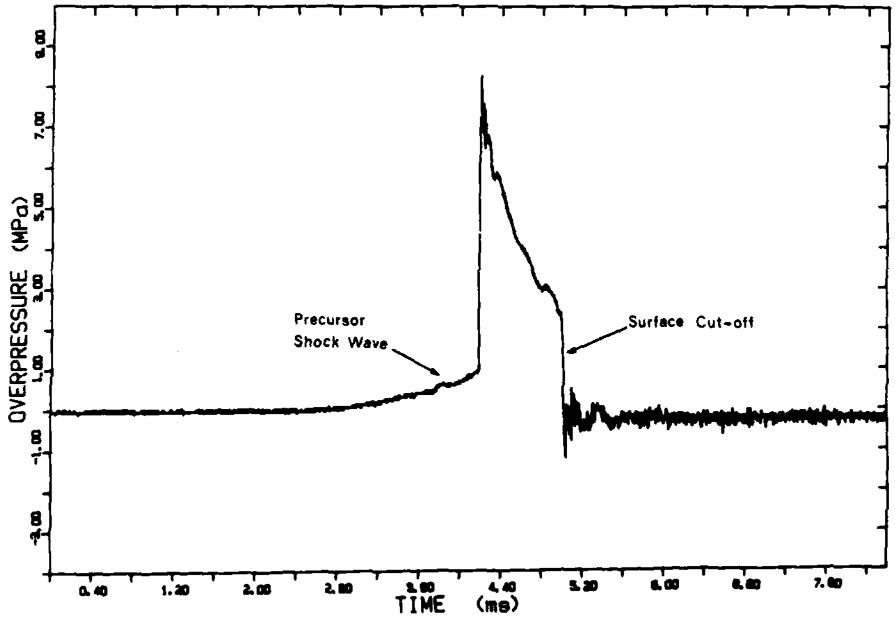



FIGURE 14 Example of a pressure record from a Mk 84 shot.

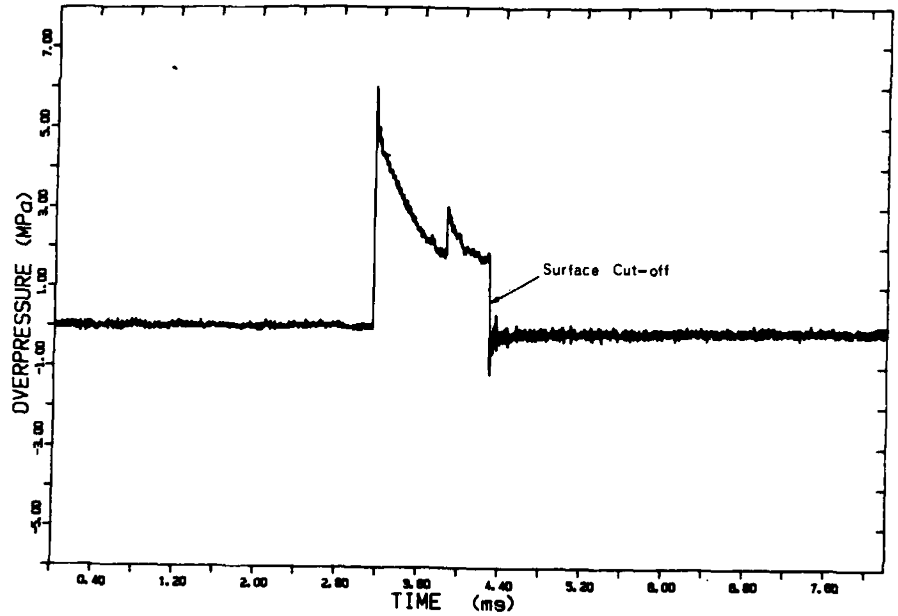



FIGURE 15 Example of a pressure record from an AS Mk 6 shot.

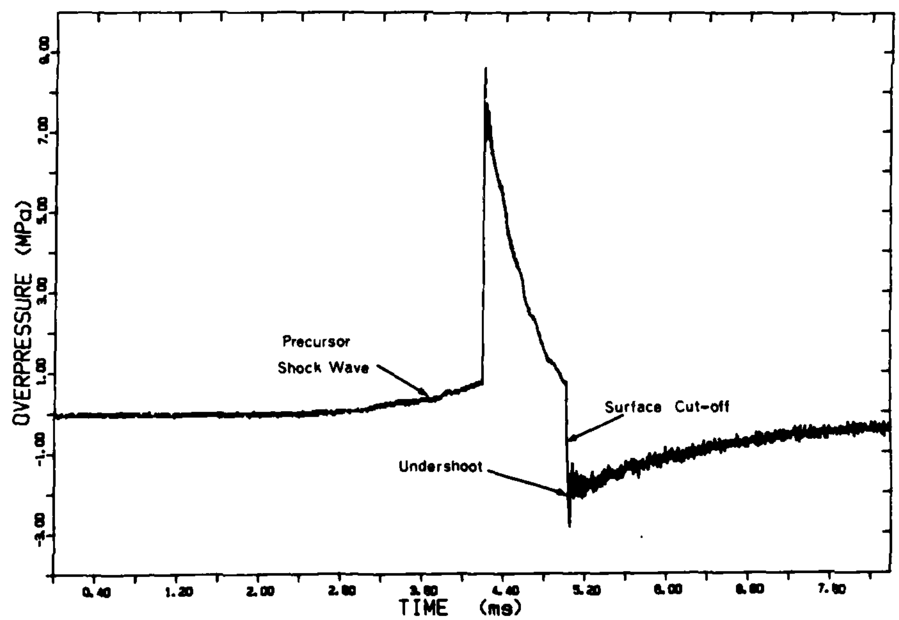



FIGURE 16 Example of a pressure record showing undershoot due to inadequate pressure gauge response.

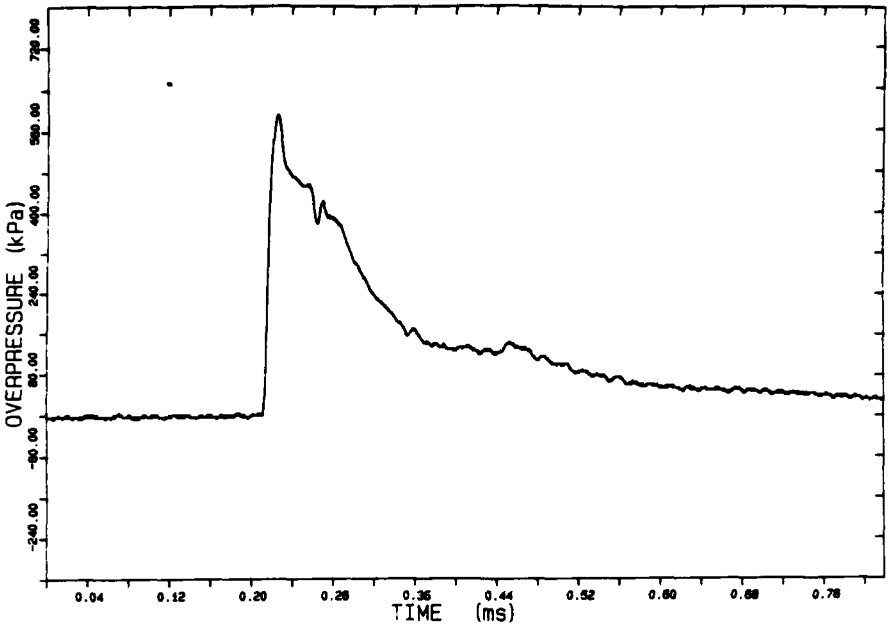



FIGURE 17 Example of a pressure gauge calibration record.

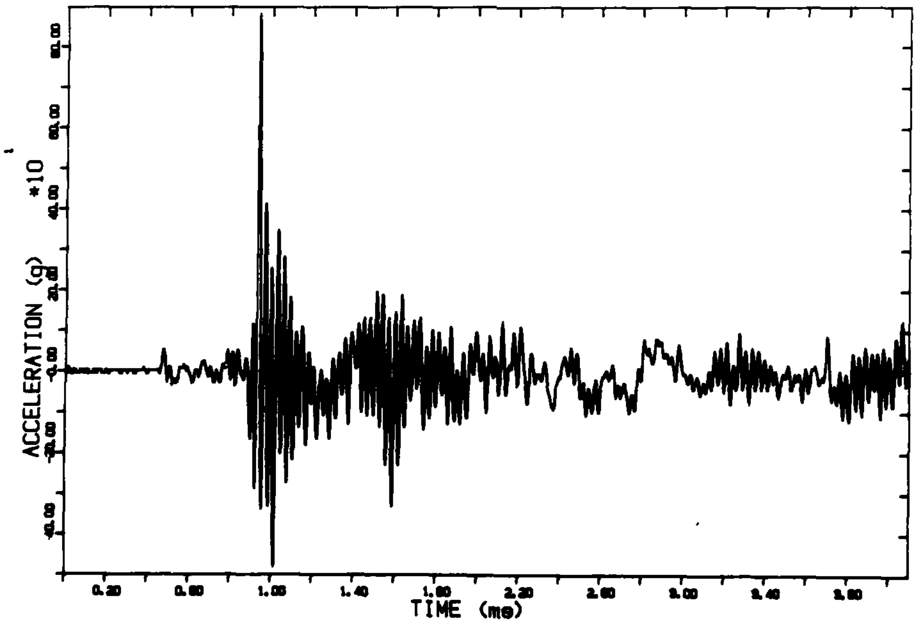



FIGURE 18 Example of an acceleration record.

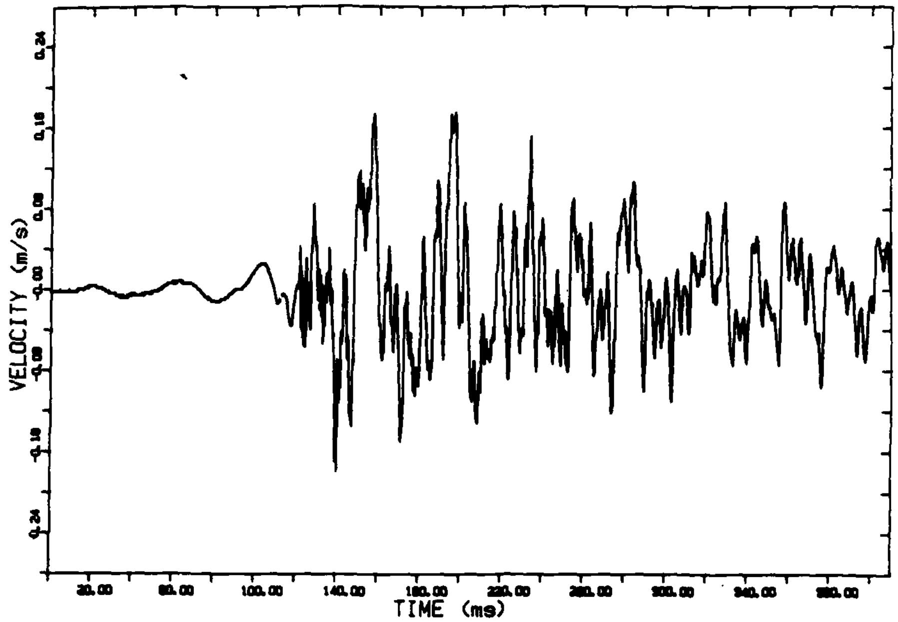



**FIGURE 19** Example of a velocity record.

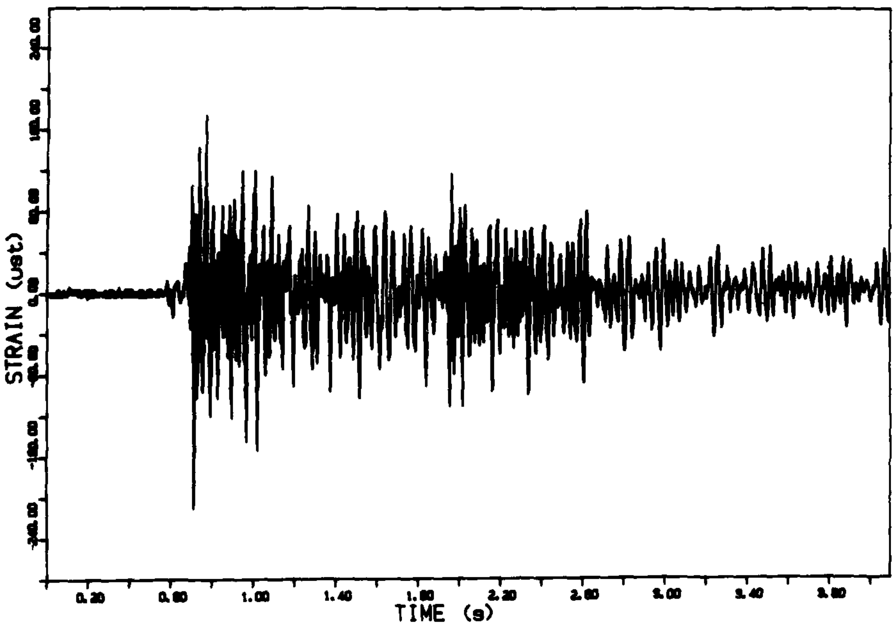



**FIGURE 20** Example of a strain record.

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TITLE

Minehunter inshore shock trials - phase 2: a limited shock trial for developing trial methodology and logistics


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ABSTRACT

Phase 2 of the Australian inshore minehunter shock trials was conducted in the ocean off the coast from Townsville during September - October, 1986. The trial was the second in a three-phase programme which ended with the first-of-class shock testing of the Royal Australian Navy's prototype glass reinforced plastic (GRP) minehunter catamaran during November-December, 1987.

Described in the report are the operations undertaken during the trial by the Materials Research Laboratory, Defence Science and Technology Organisation, Melbourne. The operations were conducted onboard an aircraft water lighter which could only be subjected to low shock levels. The operations involved explosive charge firing, the collection of underwater explosion data, and the use of shock motion measuring instrumentation and high-speed cine cameras. Some examples of typical motion and pressure-time histories are given.